COMPUTERIZED AUTOMATIC EDDY CURRENT SYSTEM FOR INSPECTION OF SURFACE CRACKS ON OIL-WELL SUCKER RODS

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INTRODUCTION

Oil-well sucker rods are subject to long-term fatigue stress. The stress often leads to failure due to cracks initiated from the rod surfaces, thereby causing severe problems in oil production. In China, the demand for surface crack inspection has lead to a search for techniques for inspecting these rods to the improve the reliability of oil-well operation, as well as for recycling thousands of used and discarded sucker rods that are stored in the oil fields.

Although several choices are available, the eddy current technique was selected for inspecting the rods because of its high sensitivity to tiny cracks, ruggedness and its low cost. In order to render the inspection insensitive to the effects of variations in permeability and improve sennsitivity ferromagnetic specimens are usually saturable magnetically. This, however, usually introduces other problems, such as additional complexity of mechanical design, increase in power, temperature rise, weight and physical sizes.

The initial question this team had to address before beginning the reseach was, "How can we design an eddy current system for inspecting of ferromagnetic materials without saturating the specimen?"

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OIL-WELL SUCKER ROD

The sucker rods (see Figure 1) are generally made of steel containing specific amounts of Mn and Cr. A sucker-rod is approximately 7/8Ó-1Ó (22.2 -25.4 mm) in diameter and 25Ó - 33Ó (7.6-10.0 m) in length. Each rod has two enlarged ends, 60 - 70 mm in diameter, for interconnection with each other in the oil well.

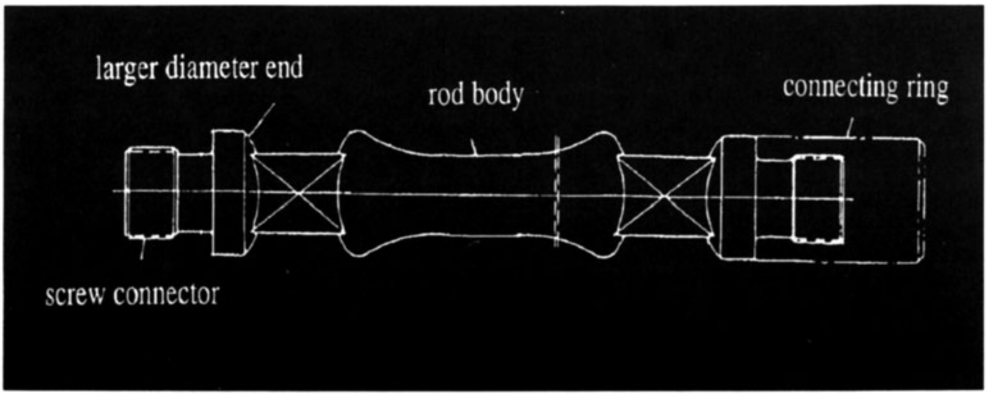

Figure 1. Mechanical drawing of a sucker rod

All of the geometrical parameters of a rod are specified with large tolerances. For example, a one inch diameter rod is specified as 24.6 - 25.5 mm in diameter. The surface conditions of a rod are normally very poor. They are rough and dirty; many new rods have coatings and many used rods have oil and grease. There can be many anomalies on the surfaces; e.g. corrosion pits, dents, rubs, protuberances and diameter thinnings, that do not hinder its normal operation and should not be indicated during inspection.

INSPECTION REQUIREMENTS

One of the defectsthat is of considerable concern is the circumferential crack. Such cracks have been associated with the rod breakdown and failure. A complete scan of the rod surface, excluding the ends, was required to locate cracks at any location on the main body surface. The inspection speed requirements were also critical due to the large volume.

An inspection system with two degrees of freedom of movement; e.g. a rod rotation plus a linear movement of a probe in the axial direction of the rod, could be an ideal scheme from a measurement viewpoint. However, it would make the mechanical design of the system complicated, due to the extremely large length-to-diameter ratio and the two big ends of the rod.

The major specifications of rod inspection systems are given below:

1. Single degree of freedom in movement of the probe, while the rod under inspection was fixed and tensed straight.
2. A complete scan of whole surface of a rod, excluding its two ends.
3. Driving speed: 0.15 m/s - 0.2 m/s.
4. Only circumferential cracks to be detected.
5. Detectable cracks should be no less than 0.3 mm deep and 3 mm long.
6. Sound alarm when a detectable crack was found.
7. Automatic sorting of rods, good and bad, by their crack depth.

EDDY CURRENT PROBE

The eddy current probe consisted of eight coils (Figure 2) with ferrite cores aligned circumferentially, to ensure full coverage of the rod surface and avoiding the need for rotating the rod. Each coil is independently spring-loaded to force contact with the rod surface. The coil tips were coated with a wear-resistant material. The special design of the probe and a proper selection of eddy scope allows detection of surface cracks without magnetic saturation. The signals are rotated appropriately to ensure that crack signals have a significant vertical component while signals from other anomalies have a predominately horizontal component. The probe was designed in the form of a spring-loaded clamp (Figure 3) that could be opened to allow the two big-ends to pass through.

INSPECTION SYSTEM

A rod was stretched on a mechanical frame (Figure 4) using hydraulic pressure, while the probe assembly was carried by a motor driven vehicle tethered using a steel rope. The output from the probe went to an eddy scope, MIZ-20A, whose operating frequency was 20-200 kHz.

The eddy scope was connected to a 486 microcomputer through an A/D and D/A card for digitization, data communication, and automatic control of the whole system. The RS-232 port of the instrument was also used to obtain transmit commands from the computer, since the entire instrument was controlled by the computer. Figure 5 depicts the system block diagram.

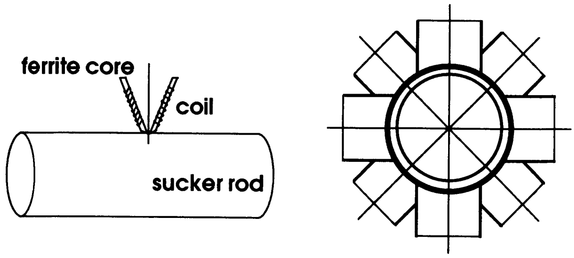

Figure 2. A schematic drawing of the probe

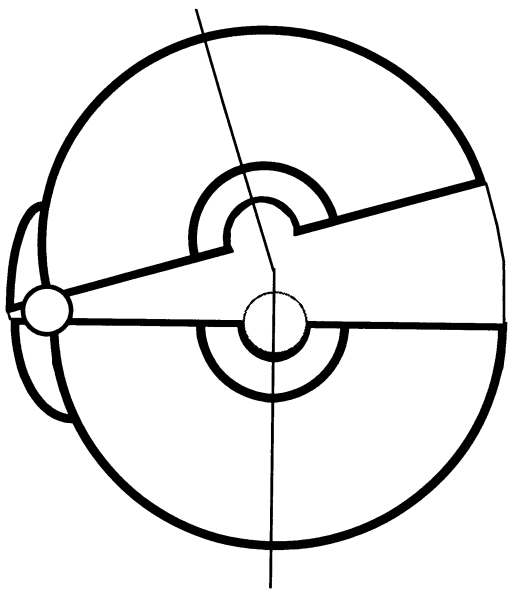

Figure 3. Clamp-type structure of the probe assembly

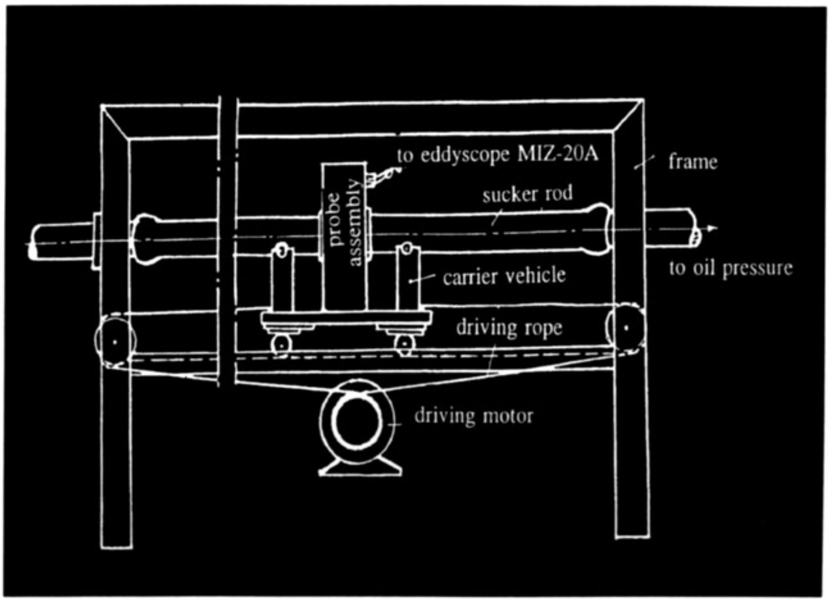

Figure 4. A scratch of the mechanical frame for sucker-rod inspection

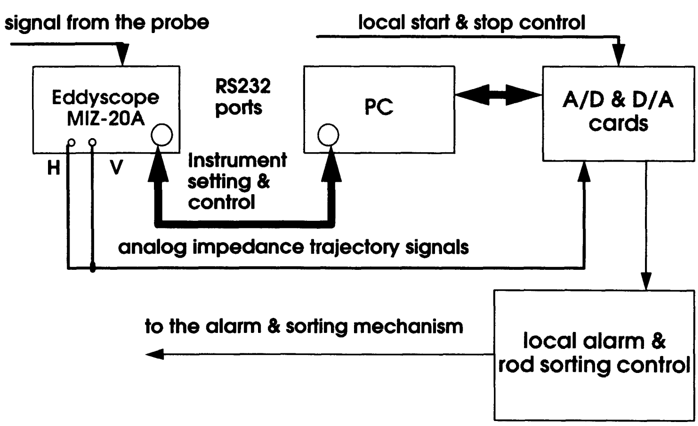

Figure 5. Sucker-rod inspection system diagram

A Microsoft Windows-based software was developed for the system operation. A multifunctional pull-down menu in Chinese (that can be in English) is available on the computer. It controls the system operation, such as the MIZ-20A menu setting, data transmission between the computer and MIZ-20A, real-time control of alarm and sorting functions, complete test data storage and subsequent manipulation or postprocessing of data.

In brief, the system classified the rod materials, detected surface cracks and automatically sorted the rods on the basis of detected crack depths. It provided additional functions, such as removing dirt, oil, and rust from the rod surface before detection.

CALIBRATION

Several artificial anomalies were made on some of the machined and cleaned rod surfaces. They are shown in Figure 6. The impedance trajectories from these calibration samples are shown on Figure 7.

The record shows that the inspection system did not generate significant vertical signal for all anomalies except the circumferential EDM notch.

LOCAL INSPECTION RECORDS

Many real defects, transverse cracks, surface rubs, diameter-thinnings, bundling marks, protuberances, corrosion pits, etc., that were found on some raw sucker-rods were also tested. Typical records of the impedance trajectories are given on Figure 8. Again, the only two signals containing significant vertical components, transverse cracks and bundling marks were circumferential crack related.

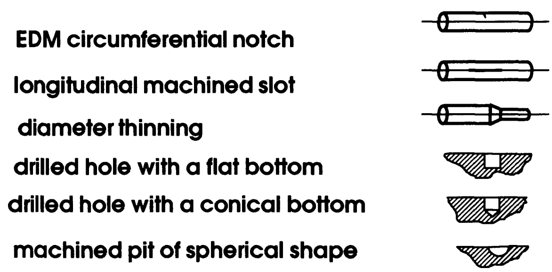

Figure 6. Calibration samples

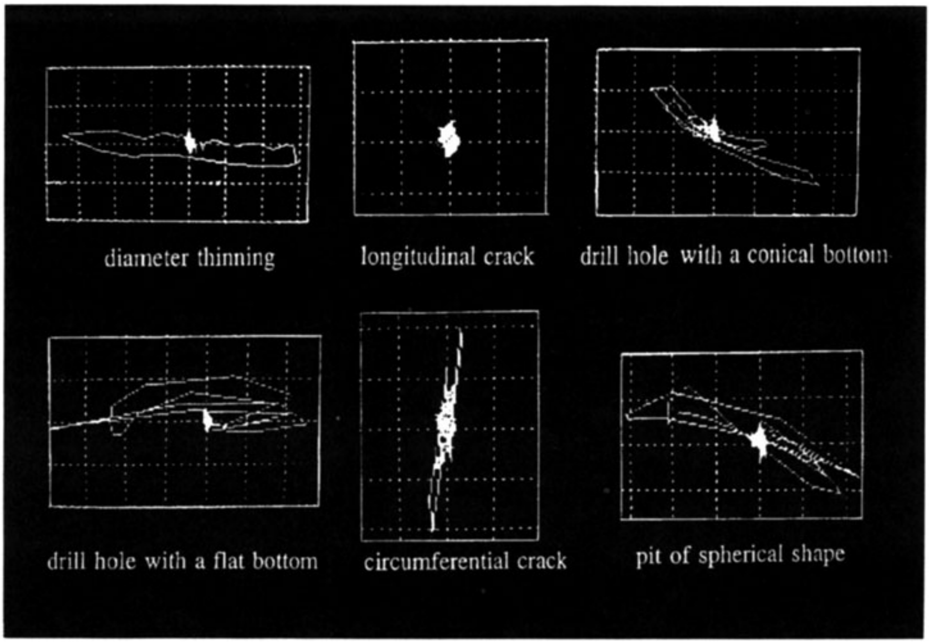

Figure 7. Impedance trajectories from the calibration samples

For final verification of the inspection system, one hundred used sucker-rods and seven new rods were scanned. Three fault alarms were generated during the inspection procedure. They were later analyzed, using the magnetic particle method, and gradual maching to remove metal. It was found that, among the three cases, two were due to real circumferential cracks with depths ranging from 0.2 mm to 0.3 mm, and one was caused by a thin, oxidized steel layer forged on the surface.

The system has been successfully used in the Daiqing Oil Field, the most productive field in China, since early 1991.

CONCLUSION

An eddy current inspection system has been built for inspection of transverse cracks on oil-well sucker-rods. This system provides an audible alarm and automatic sorting for transverse cracks with a depth greater than 0.2 mm to 0.3 mm. The system is designed not to generate an alarm for all other anomalies on the rod surface.

The low cost system is simple and efficient. As the rods are notmagnetically saturated, a system with a single degree of freedom of movement is adequate and only low-level rod surface cleaning is required.

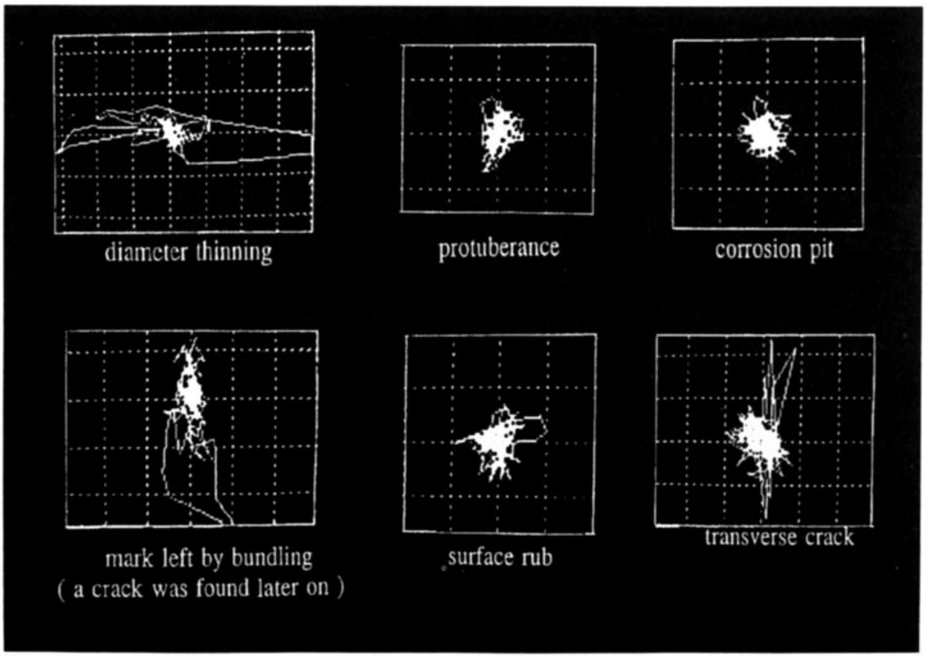

Fig. 8. Impedance trajectories from some real defects

ACKNOWLEDGMENT

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